# STORM WATER ~~DETENTION~~ MANAGEMENT

## DRAINAGE

A. No building structure, or use of land for other than agricultural purposes shall be constructed on a lot or tract of land where the total impervious land cover, as proposed, shall exceed 20,000 square feet (excluding publicly accepted streets) until a drainage plan as it relates to the proposed use of the land shall be approved by the City Engineer. The Chief Building Official shall not issue a building permit for such improvements until the drainage plan required by this section shall be approved by the City Engineer.

B. The drainage plan as required by this section shall include but not be limited to a site plan showing existing proposed buildings, storm drainage facilities, ground cover, site construction plans with grading plan, and drainage system; drainage facility design data including area map, engineering calculations, area of impervious cover and total land area.

C. The drainage plan shall be prepared and approved using the standards of the City Engineer, as set forth in the Manual of Standard Designs and Details.

D. Impervious ground cover for the purpose of this manual shall mean: Asphalt, concrete, stone, brick, terrazzo, roofing, clay tile, or any other natural or man-made material that is resistant to the absorption of surface water.

E. The City Engineer shall not approve a drainage plan where the stormwater runoff will be increased by the proposed impervious cover for storms up to and including those expected to occur one in ten years unless adequate provisions are made to control the excess runoff so that the rate of stormwater runoff is equivalent to the rate of stormwater runoff prior to the installation of the impervious ground cover. Provided however, the drainage plan as required by this section shall be waived if the tract being developed is a part of a larger tract for which the plan for control of excess has already received prior approval and has been implemented and the runoff from the site to be developed is not expected to exceed the standard used in granting said prior approval. Provided further, the drainage plan may waive any requirements for detention of water when the tract being developed is located within a designated floodway or flood hazard area, as provided in Ordinance No. 786, and the natural flow of the water drains into the said land subject to the floodway regulations.

F. In the event that literal interpretation of this ordinance creates an undue hardship, the applicant may appeal to the Subdivision Review Committee for a variance in whole or in part from this ordinance.

G. No part of this section shall be applied to structures existing prior to the effective date of this ordinance nor shall existing impervious ground cover be used in the calculation of runoff.

ADOPTED this the ___14th___ day of ___August,___ 1980, to be effective November 1, 1980.

_____
DONALD C. McGLOHON, MAYOR

ATTEST:

_Lois D. Worthington_
LOIS D. WORTHINGTON, CITY CLERK

## DESIGN AND CONSTRUCTION CRITERIA

The following criteria will be used for the design and construction of all stormwater impoundment facilities within extraterritorial boundaries of the City of Greenville.

### GENERAL:

- Design and installation of all stormwater impoundment facilities must comply with applicable Federal, State, and local laws. Attention should be given to the City of Greenville Soil Erosion and Sediment Control Ordinance and the North Carolina Dam Safety Law of 1967.

- In no case shall a habitable structure be located within the impoundment area of any stormwater storage facility.

- No utilities (sewer lines, power lines, water lines, etc.) shall be located within or immediately around any impoundment facility.

- All impoundment facilities will be considered permanent.

- All facilities shall be protected by a "Drainage ~~Detention~~ Easement" recorded at the Pitt County Register of Deeds office.

*OK as a common Lot*

### SITE LOCATION:

- It is recommended that stormwater impoundment facilities be located on the site from which the runoff to be controlled is generated. However,

- Off-site impoundments facilities are acceptable provided the land area involved with the facility is delineated on an acceptable map and officially recorded at the Pitt County Register of Deeds office as a permanent "Drainage Detention Easement". Also, an official commitment to maintenance of the facility will be required.

SITE PLAN: ← Stormwater

-A ~~site~~ Stormwater plan acceptable by the City Engineer's standards will include the following:

I. Development Plan

A. Map Features:
-Legend
-North Arrow
-Vicinity Map
-Title block with development name, owner, engineering firm, engineer's seal and signature
-Scale

B. Topographical Features:
-Original contours at not more than 2' intervals
-Existing drainage patterns, including streams, ponds, etc.
-Boundary lines
-Existing streets and buildings
-100-year flood line or building restriction floodlines, where applicable

C. Site Plan:
-Proposed structures, roads, buildings, paved areas
-Storm drainage system, including locations, sizes, lengths, and all structures with drainage area maps and calculations
-Location and grade of all swales and berms
-Identify all critical areas
-Show type and placement of all permanent erosion control measures
-Contours of proposed sites
-Grading plan
-Existing and planned ground cover
-Typical street cross-section
-Proposed profiles of roadways

REPLACE

II  Narrative

A.  Calculations of runoff

B.  Calculations for design of stormwater impoundment facility

C.  Staging of the project

D.  Soil conditions:
    - Soil type
    - Susceptibility to erosion and preventative measures
    - Seeding formula

~~STORAGE VOLUME~~
~~ATTENUATION~~

**NUTRIENT REDUCTIONS:**

- Various methods of which impoundment storage volume is approximated may be utilized; however, the result must at least equal that volume approximated using the method described within this manual.

~~All facilities constructed to achieve nutrient reductions shall meet all requirements specified in the NC Division of Water Quality Stormwater Best Management Practices Manual.~~

**REPLACE**

-All required storage volume approximations must be included with submitted design.

PRIMARY OUTLET DEVICE:

-All outlet devices must be constructed adhering to current construction standards as described in the City of Greenville's "Manual of Standard Designs and Details".

-Alternate outlet devices not referred to in this publication may be approved

-Off-site water bodies
-Total impervious area in square feet (existing and planned)
-Soil types

REVISIONS
DESCRIPTION
NO. DATE

(A) 2 copies of the Storm Water Management Plan showing:

    1. General:
    \_\_\_\_\_ Vicinity Map
    \_\_\_\_\_ Legend, North arrow and scale
    \_\_\_\_\_ Title Block with development name, owner, engineering firm, engineer's seal, and signature
    \_\_\_\_\_ Existing and proposed contours at not more than 2' intervals
    \_\_\_\_\_ Flood boundaries identified
    \_\_\_\_\_ Existing and proposed improvements (built upon area)
    \_\_\_\_\_ Existing and proposed ground cover

    2. Drainage:
    \_\_\_\_\_ Existing and proposed drainage patterns and structures (BMP's, pipe systems, ditches/streams, ponds, etc.)
    \_\_\_\_\_ Size, length and grade of pipes and swales
    \_\_\_\_\_ Drainage area map
    \_\_\_\_\_ Soil types

    3. Calculations:
    \_\_\_\_\_ First Flush
    \_\_\_\_\_ Attenuation of 1-year, 24-hour storm
    \_\_\_\_\_ Underdrain calculations (if necessary)
    \_\_\_\_\_ Sizing of treatment area
    \_\_\_\_\_ Pipe/swale sizing calculations

    4. Maintenance:
    \_\_\_\_\_ BMP maintenance agreement
    \_\_\_\_\_ Check to record agreement (Pitt County Register of Deeds)
    \_\_\_\_\_ Maintenance plan
    \_\_\_\_\_ Adequate access to perform required maintenance
    \_\_\_\_\_ Easement (if required)

    5. Erosion Control:
    \_\_\_\_\_ Construction sequence
    \_\_\_\_\_ Location of BMP erosion control measures (if necessary)

(B) 2 copies of the Storm Water Management Narrative showing:

    \_\_\_\_\_ Description of project
    \_\_\_\_\_ Calculations of runoff
    \_\_\_\_\_ Calculations for design of stormwater impoundment facility
    \_\_\_\_\_ Staging of the project
    \_\_\_\_\_ Soil conditions:
    \_\_\_\_\_ Soil type
    \_\_\_\_\_ Susceptibility to erosion and preventive measures
\_\_\_\_\_ Seeding formula

at the discretion of the City Engineer. Such approval must be specifically requested upon submittal of the drainage plan.

- The water velocity generated by any outlet device must meet the requirements set forth by the City of Greenville Soil Erosion and Sediment Control Ordinance.

SECONDARY OUTLET DEVICE (EMERGENCY SPILLWAY):

- It is recommended that all vegetated spillways be constructed in nonfilled or cut areas. However,

- Emergency spillways may be constructed in fill areas provided they are asphalt or concrete lined and have sufficient approach and exit areas.

- Any emergency spillways as a minimum must pass the peak 100-year 10-year flood after the storage facility has reached its capacity.

FACILITY LIFE:

- All stormwater impoundments are to be permanent facilities.

- All materials used in the construction of a stormwater impoundment facility must have a life expectancy equal to that of the total facility or a regularly scheduled replacement program must be provided.

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APPROVED:DATE May 8, 1980

STD. NO. 6005 REV.

On-site detention involves the storage of stormwater runoff and the controlled release of that runoff and is applicable for all proposed sites having 20,000 square feet or more of impervious cover. The excess runoff must be controlled so that the rate of stormwater runoff from the developed site is less than or equal to the rate of stormwater runoff prior to the installation of the impervious cover for storms up to and including the 10-year storm. [1 year (80% of 2 year)] All impoundments will have an emergency device or "spillway" that will safely pass the 100-year storm. The weir will be sized to carry the 100-year storm safely with an additional one foot of freeboard. The procedure is described in the sediment basin design example contained in Section 20 of this manual.

Flood routing is an algebraic method for determining the time and magnitude of a particular flood situation with regard to the rate of inflow storage versus the rate of outflow discharge. For the purpose of this manual, the routing procedure is based on the procedure described in the "Design Approaches for Stormwater Management in Urban Areas" by Dr. H. Rooney Malcom, Jr. of N. C. State University. This procedure is described in the example included within this chapter.

## Maximum Permissible Release Rate

The maximum release rate must be limited to that rate of runoff discharged from the site immediately prior to the proposed development during the 10-year storm. [1 year (80% of 2 year)] This rate can be calculated according to the Rational Method described in this manual.

A group of hydrographs can be developed where the intensity is varied by using storms with different durations. The volume of runoff associated with each hydrograph is calculated by multiplying the maximum runoff rate with the respective storm duration (Note that runoff is measured in cubic feet per second and the duration is in minutes).

Once the hydrographs have been developed it is necessary to convert the maximum runoff rates for each rainfall to storm runoff volumes. These volumes should be computed in cubic feet.

[Handwritten margin note: required to meet the Stormwater Program. City of Greenville's Management Program. See this program and any ammendments for requirements]

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CITY OF GREENVILLE, N.C.— ENGINEERING DEPT.

APPROVED: DATE May 8, 1980

| STD. NO. | REV. |
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| 6006 |  |

This is only an approximation which is applicable to small basins (see Example 1 for a typical design). Many different methods may be used in the design of impoundment facilities and innovative designs will be considered by the City Engineer provided the maximum permissible release rate and the storage facility requirements are met with a safety factor (Table 60-2 indicates some alternate methods of detention). In all cases, the design will be routed for confirmation.

## TABLE II

### Advantages and Disadvantages of Measures for Reducing and Delaying Stormwater Runoff

| Measure | Advantages | Disadvantages |
|---------|------------|---------------|
| A. Cisterns and covered ponds | 1. Water may be used for:<br>  a. Fire protection<br>  b. Watering lawns<br>  c. Industrial processes<br>  d. Cooling purposes<br>2. Reduce runoff while only occupying small area<br>3. Land or space above cistern may be used for other purposes. | 1. Expensive to install<br>2. Cost may be restrictive if the cistern must accept water from large drainage areas<br>3. Require slight maintenance<br>4. Restricted access<br>5. Reduced available space in basements for other areas |
| B. Rooftop gardens | 1. Esthetically pleasing<br>2. Runoff reduction<br>3. Reduce noise levels<br>4. Wildlife enhancement | 1. Higher structural loadings on roof and building<br>2. Expensive to install and maintain |

TABLE II, Continued

| Measure | Advantages | Disadvantages |
|---|---|---|
| C. Surface pond storage (usually residential areas) | 1. Controls large drainage areas with low release<br>2. Esthetically pleasing<br>3. Possible recreation benefits:<br>  a. Boating<br>  b. Ice skating<br>  c. Fishing<br>  d. Swimming<br>4. Aquatic life habitat<br>5. Increases land value of adjoining property | 1. Require large areas<br>2. Possible pollution from stormwater and siltation<br>3. Possible mosquito breeding areas<br>4. May have adverse algal blooms as a result of eutrophication<br>5. Possible drowning<br>6. Maintenance problems |
| D. Ponding on roof by constricted down-spouts | 1. Runoff delay<br>2. Cooling effect for building:<br>  a. Water on roof<br>  b. Circulation through<br>3. Roof ponding provides fire protection for building (roof water may be tapped in case of fire) | 1. Higher structural loadings<br>2. Clogging of constricted inlet requiring maintenance<br>3. Freezing during winter (expansion)<br>4. Waves and wave loading<br>5. Leakage of roof water into building (water damage) |
| E. Increased roof roughness:<br>a. Rippled roof<br>b. Gravel on roof | 1. Runoff delay and some reduction (detention in ripples or gravel) | 1. Somewhat higher structural loadings |

TABLE II, Continued

| Measure | Advantages | Disadvantages |
|---|---|---|
| F. Porous pavement (parking lots and alleys):<br>a. Gravel parking lot<br>b. Holes in impervious pavements (1/4 in.) filled with sand | 1. Runoff reduction (a and b)<br>2. Potential groundwater recharge (a and b)<br>3. Gravel pavements may be cheaper than asphalt or concrete (a) | 1. Clogging of holes or gravel pores (a and b)<br>2. Compaction of earth below pavement or gravel decreases permeability of soil (a and b)<br>3. Groundwater pollution from salt in winter (a and b)<br>4. Frost heaving for impervious pavement with holes (b)<br>5. Difficult to maintain holes (b)<br>6. Grass or weeds could grow in porous pavement (a and b) |
| G. Grassed channels and vegetated strips | 1. Runoff delay<br>2. Some runoff reduction (infiltration recharge)<br>3. Esthetically pleasing:<br>  a. Flowers<br>  b. Trees | 1. Sacrifice some land area for vegetated strips<br>2. Grassed areas must be mowed or cut periodically (maintenance costs) |
| II. Ponding and detention measures on impervious pavement:<br>a. Rippled pavement | 1. Runoff delay (a, b, and c)<br>2. Runoff reduction (a and b) | 1. Somewhat restricted movement of vehicles (a)<br>2. Interferes with normal use (b and c) |

| Measure | Advantages | Disadvantages |
|---|---|---|
| b. Basins<br>c. Constricted inlets | | 3. Damage to ripple pavement during snow removal (a)<br>4. Depressions collect dirt and debris (a, b, and c) |
| 1. Reservoir or deten-<br>tion basin | 1. Runoff delay<br>2. Recreation benefits<br>  a. Ice skating<br>  b. Baseball, football, etc., if land is provided<br>3. Esthetically pleasing<br>4. Could control large drainage areas with low release | 1. Considerable amount of land is necessary<br>2. Maintenance costs:<br>  a. Mowing grass<br>  b. Herbicides<br>  c. Cleaning periodically (silt removal)<br>3. Mosquito breeding area<br>4. Siltation in basin |
| J. Converted septic tank for storage and groundwater recharge | 1. Low installation costs<br>2. Runoff reduction (infiltration and storage)<br>3. Water may be used for:<br>  a. Fire protection<br>  b. Watering lawns and gardens<br>  c. Groundwater recharge | 1. Requires periodic maintenance (silt removal)<br>2. Possible health hazard<br>3. Sometimes requires a pump for emptying after storm |

TABLE II, Continued

| Measure | Advantages | Disadvantages |
|---|---|---|
| K. Groundwater recharge:<br>  a. Perforated pipe<br>    or hose<br>  b. French drain<br>  c. Porous pipe<br>  d. Dry well | 1. Runoff reduction<br>   (infiltration)<br>2. Groundwater recharge<br>   with relatively clean<br>   water<br>3. May supply water to<br>   garden or dry areas<br>4. Little evaporation loss | 1. Clogging of pores or<br>   perforated pipe<br>2. Initial expense of<br>   installation (materials) |
| L. High delay grass<br>  (high roughness) | 1. Runoff delay<br>2. Increased infiltration | 1. More difficult to mow |
| M. Routing flow over<br>  lawn | 1. Runoff delay<br>2. Increased infiltration | 1. Possible erosion or scour<br>2. Standing water on lawn in<br>   depressions |

## SWD-01

| $t/t_p$ | $Q/Q_p$ |
|---|---|
| 0.5 | 0.4 |
| 1.0 | 1.0 |
| 1.5 | 0.6 |
| 2.0 | 0.3 |
| 3.0 | 0.07 |

## SWD-03

PITT COUNTY

| 5-yr., 6hr. Rainfall | 3.86 in. |
| 10-yr., 6hr. Rainfall | 4.40 In. |
| 25-yr., 6hr. Rainfall | 5.24 In. |
| 50-yr., 6hr. Rainfall | 5.85 In. |
| 100-yr., 6hr. Rainfall | 6.60 In. |

## SWD-02

| $t/t_p$ | (1) $Q/Q_p$ | OR (2) $Q/Q_p$ |
|---|---|---|
| 0.0 | 0.00 | 0.00 |
| 0.1 | 0.015 | 0.024 |
| 0.2 | 0.075 | 0.095 |
| 0.3 | 0.16 | 0.21 |
| 0.4 | 0.28 | 0.35 |
| 0.5 | 0.43 | 0.50 |
| 0.6 | 0.60 | 0.65 |
| 0.7 | 0.77 | 0.79 |
| 0.8 | 0.89 | 0.90 |
| 0.9 | 0.97 | 0.98 |
| 1.0 | 1.00 | 1.00 |
| 1.1 | 0.98 | 0.98 |
| 1.2 | 0.92 | 0.90 |
| 1.3 | 0.84 | 0.85 |
| 1.4 | 0.75 | 0.74 |
| 1.5 | 0.66 | 0.64 |
| 1.6 | 0.56 | 0.55 |
| 1.7 | 0.49 | 0.48 |
| 1.8 | 0.42 | 0.42 |
| 1.9 | 0.37 | 0.36 |
| 2.0 | 0.32 | 0.31 |
| 2.1 | 0.28 | 0.27 |
| 2.2 | 0.24 | 0.24 |
| 2.3 | 0.21 | 0.20 |
| 2.4 | 0.18 | 0.18 |
| 2.5 | 0.15 | 0.15 |
| 2.6 | 0.13 | 0.13 |

FOR STEP FUNCTION, (2):

for $0 \leq t \leq 1.25\, t_p$:

$$Q = \frac{Q_p}{2}\left[1 - \cos\left(\frac{\pi t}{t_p}\right)\right]$$

$\left(\frac{\pi t}{t_p}\right)$ is in radians

for $t > 1.25\, t_p$:

$$Q = 5.37\, Q_p\, e^{-1.42\, t/t_p}$$

(1) FROM U.S. BUREAU OF RECLAMATION, DESIGN OF SMALL DAMS, 2nd EDITION, DENVER, COLORADO

(2) STEP FUNCTION, DESIGN APPROACHES TO STORMWATER MANAGEMENT, DR. H.R. MALCOM, JR., N.C.S.U.

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CITY OF GREENVILLE, N.C. — ENGINEERING DEPT.

DIMENSIONLESS HYDROGRAPH COORDINATES

APPROVED: DATE May 8, 1980

# PARKING LC. DETENTION

## PROBLEM:

An automobile dealership is to be constructed on a currently undeveloped six-acre tract.

## GIVEN DATA:

The site will become almost totally impervious by the placement of buildings and paved parking areas.

## DESIGN REQUIREMENT

A.  Design a stormwater impoundment facility that will control the increased runoff created by the site development, so that the 10-year runoff rate from the developed site is equivalent to the 10-year rate from the site prior to development.

B.  The facility must be located on site.

## MAXIMUM PERMISSIBLE RELEASE RATE:

Assume: Maximum permissible release rate = peak 10-year discharge for site prior to development. C = 0.25 (Chart SD-3), A= 6 AC. Using topo map of unimproved site, locate the point of design and the most remote point from the design site.

| | |
|---|---|
| Elevation of remote point | 62 ft |
| Elevation of point of design | 59 ft |
| Difference in elevation | 3 ft |

Length of travel   300 ft

$Tc = (3.6) x2 = 7.2$ minutes (Chart SD-2). For Overland flow, Multiply Tc by 2
Assume Tc = Duration . . . i = 7.0 in/hr (Chart SD-1)

$Q = CiA = (0.25)(7.0)(6) = 10.5$ SAY 11 cfs

Maximum Permissible release Rate = 11 cfs

## PEAK RUNOFF: (DEVELOPED)

Calculate the peak runoff rate for a 10-year storm assuming the site is
developed. C(developed) = 0.90 (Chart SD-3). Using the site plan showing
proposed conditions, locate the point of design and the most remote point
on the site.

| | |
|---|---|
| Elevation of remote point | 60 ft |
| Elevation of point of design | 58 ft |
| Difference in elevation | 2 ft |

Length of travel      300 ft

$Tc = (4.3)(0.4) = 1.72$ minutes (Chart SD-2)
Assume minimum allowable $Tc = 5$ minutes
Assume $Tc = $ Duration .... $i = 7.5$ in/hr (Chart SD-1)

$$Q = CiA = (0.90)(7.5)(6) = 40.50 \text{ SAY } 41 \text{ cfs}$$

Peak Inflow (developed) = 41 cfs

## INFLOW HYDROGRAPH:

Let the hydrograph peak at the 10-year Rational Flow with C = 0.90. Set the
volume under the hydrograph at the 10-year, 6-hr runoff: use CN = 90
(Rf:SCS TR-55)

A. Peak flow: Qp (developed conditions) = CiA = 41 cfs

B. Runoff:    $S = 1000/CN - 10 = 1.11$ inches (Rf:SCS TR-55)

C. Precipitation (Rf: U.S. Weather Bureau TP-40)

### Pitt County

| | |
|---|---|
| 5-year 6hr rainfall ........ | 3.86 inches |
| 10-year 6hr rainfall ....... | 4.40 inches |
| 25-year 6hr rainfall ....... | 5.24 inches |
| 50-year 6hr rainfall ....... | 5.85 inches |
| 100-year 6hr rainfall ...... | 6.60 inches |

P = 10-year, 6-hr rain = 4.4( :hes for Pitt Co.

$$\text{Runoff} = \frac{(P - 0.2S)^2}{P + 0.8S}; \quad 3.30 \text{ inches (Rf: SCS TR-55)}$$

= 3.30 inches (Rf: SCS TR-55)

D. Time to Peak: Use the pattern hydrograph (Rf - SCS, National Engineering Handbook) to set Tp such that the hydrograph peaks at 41 cfs and contains 3.3 inches of runoff. Set the volume under the hydrograph at the 10-year, 6-hr runoff.

$$T_p = \frac{Vol}{1.37 Q_p} = \frac{(3.30 \text{ in})(6 \text{ AC})}{(1.37)(41 \text{cfs})} \left\{\frac{1 \text{ ft}}{12 \text{ in}}\right\} (43560. \text{ ft}^2/\text{AC})(1/60. \text{ min/sec})$$

$$T_p = 21.3 \text{ min, SAY } \underline{21 \text{ min}}$$

┌─────────────────────┐
│  Inflow Hydrograph  │
│                     │
│    $Q_p$ = 41 cfs   │
│                     │
│    $T_p$ = 21 min   │
└─────────────────────┘

## STORAGE REQUIRED:

Estimate Storage by the Triangular Hydrograph Approximation

$$S_r = \left(\frac{Q_p}{2} - Q_p\right) T_p \quad \text{Note: Qo is Max. Permiss. Outflow}$$

$$S_r = (41 \text{cfs} - 11 \text{cfs})(21 \text{min})(60 \text{sec/min}) = 37800 \text{ ft}^3$$

$$\underline{S_r = 37,800 \text{ ft}^3 \text{ Estimated Storage Required}}$$

The parking lot is designed to move the runoff to one side where a 125 ft. wide, 12 in. depression will detain the excess runoff. For design purposes the depression may be assumed to have vertical sides but in fact will have driveway type ramps to make it available for parking.

Knowing the volume, depth, an... .dth;

Length $= 37,800/(125)\ (\mathbf{Z}) = 302.4$ ft SAY 305 ft

Storage $= (125)\ (305)\ (Z)$     $Z =$ ft, Storage $-$ ft

Storage $= 38,125\ (Z)$
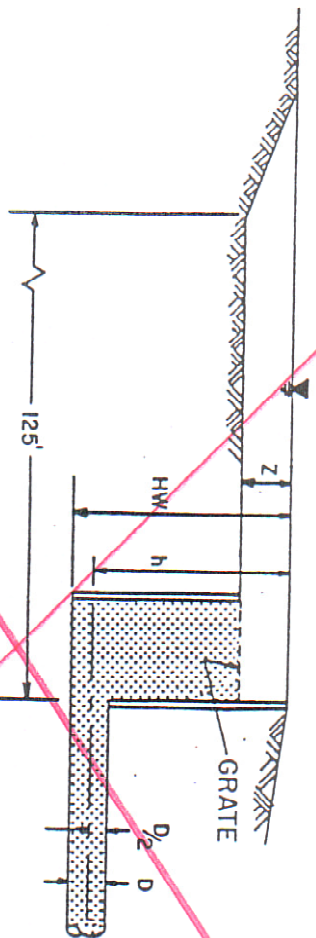


L = 305'
W = 125'
D = 15"
S = 38,125 ft³

## OUTLET DEVICE:

Knowing the maximum release rate (11 cfs), design a device which will suit the impoundment and properly control the runoff.

Use a grate(s) located at the back of the curb at the low spot in the parking lot. Design the grate with sufficient area between the bars to allow for a flow of at least twice the maximum release rate to allow for the possibility of trash collecting in the grate.

Choose a pipe(s) that will cause the water to pond at a depth of 12 inches in the parking lot while operating at 11 cfs. Use the orifice equation or Chart SD-b for concrete pipes to select the appropriate number and size of the pipe(s).

| NO. | DATE | DESCRIPTION |
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REVISIONS

APPROVED: DATE May 8, 1980

STD. NO. 60.16   REV.

$$Q = C_D A \sqrt{2gh} \quad \ldots \ldots \quad \text{Orifice E\:ion}$$

where:

$Q$ = 11 cfs (Peak Outflow)
$C_D$ = 0.58 (Square edge with headwall)
$g$ = 32.2 ft/sec (acceleration due to gravity)
$h$ = head from the centerline of the pipe (ft)
$A$ = Cross-sectional area of pipe (ft)

Choose concrete pipe(s) with $Q = 11$ cfs & $C_D = 0.58$

| No. Pipes | Dia. | HW |
|-----------|------|-----|
| 1 | 12 | 9.6 |
| 1 | 15 | 4.3 |
| 2 | 12 | 2.8 |

—Use a 15" conc. pipe with $h = 3.68$ ft.
and HW = 4.3 ft.

## ROUTING FOR CONFIRMATION:

A.  Stage Storage Relation: Using the Storage facility dimensions, the stage storage relationship can easily be calculated with the following equation

$$S = 38,125(Z) \quad (Z = 0, \text{ is the parking lot surface})$$

B.  Stage Discharge Relation: Use the orifice equation with one 15 inch pipe, $C_D = 0.58$, with the invert located 3.3 ft. below the parking lot surface.

$$Q = C_D A \sqrt{2gh}$$

Parking Lot (Z=0)

| Water Level (ft) | Storage (cu ft) | Discharge (cfs) |
|------------------|-----------------|-----------------|
| 0.5 | 0 | 4.04 |
| 1.0 | 0 | 5.71 |
| 2.0 | 0 | 8.08 |
| 2.68 | 0 | 9.35 |
| 2.88 | 7625 | 9.69 |
| 3.08 | 15250 | 10.02 |
| 3.28 | 22875 | 10.34 |
| 3.48 | 30500 | 10.66 |
| 3.68 | 38125 | 10.96 |

Plot on Graph 1 ——  Plot on Graph 2

(Note) Neglect the storage in the pipe and grate.

# INFLOW HYDROGRAPH:

$Q_p$ = 41 cfs  } Previously computed
$T_p$ = 21 min  }

Plot t and Q for
Inflow Hydrograph

Dimensionless Hydrograph Coordinates
(To be used for the 6-hour approximation)   (Reference DE-02b)

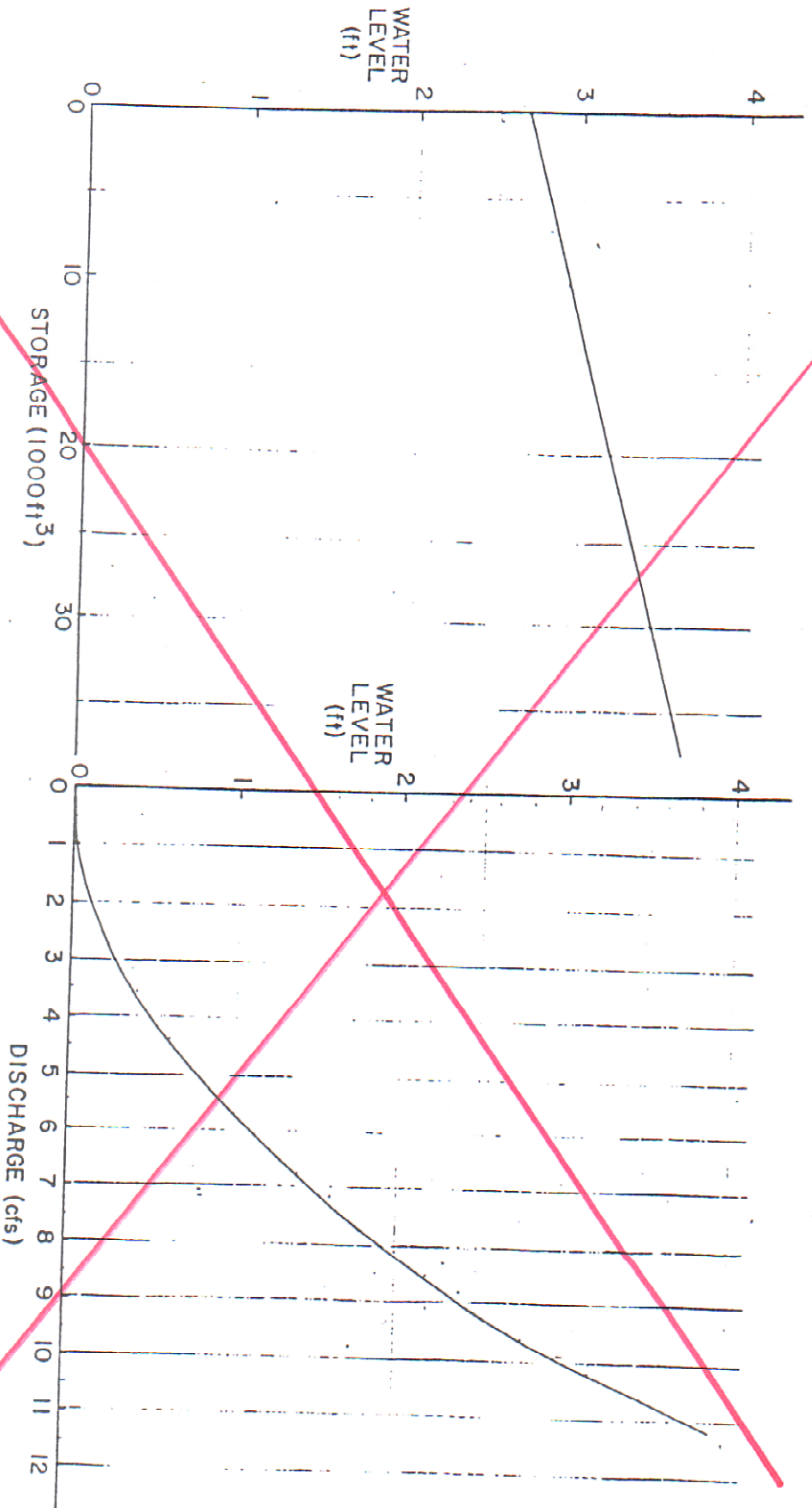| t/t_p | Q/Q_p (Step Function) | t (t/t_p x T_p) | Q (Q/Q_p x Q_p) |
|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 |
| 0.1 | 0.024 | 2.1 | 0.98 |
| 0.2 | 0.C95 | 4.2 | 3.90 |
| 0.3 | 0.21 | 6.3 | 8.61 |
| 0.4 | 0.35 | 8.4 | 14.35 |
| 0.5 | 0.50 | 10.5 | 20.50 |
| 0.6 | 0.65 | 12.6 | 26.65 |
| 0.7 | 0.79 | 14.7 | 32.39 |
| 0.8 | 0.90 | 16.8 | 36.90 |
| 0.9 | 0.98 | 18.9 | 40.18 |
| 1.0 | 1.00 | 21.0 | 41.00 |
| 1.1 | 0.98 | 23.1 | 40.18 |
| 1.2 | 0.90 | 25.2 | 36.90 |
| 1.3 | 0.85 | 27.3 | 34.85 |
| 1.4 | 0.74 | 29.4 | 30.34 |
| 1.5 | 0.64 | 31.5 | 26.24 |
| 1.6 | 0.55 | 33.6 | 22.55 |
| 1.7 | 0.48 | 35.7 | 19.68 |
| 1.8 | 0.42 | 37.8 | 17.22 |
| 1.9 | 0.36 | 39.9 | 14.76 |
| 2.0 | 0.31 | 42.0 | 12.71 |
| 2.1 | 0.27 | 44.1 | 11.07 |
| 2.2 | 0.24 | 46.2 | 9.84 |
| 2.3 | 0.20 | 48.3 | 8.20 |
| 2.4 | 0.18 | 50.4 | 7.38 |
| 2.5 | 0.15 | 52.5 | 6.15 |
| 2.6 | 0.13 | 54.6 | 5.33 |

Step Function: For $0 \leq t \leq 1.25t_p$:  $Q = Q_p/2(1-\cos(t/t_p))$
For $t \leq 1.25t_p$:  $Q = 5.37Q_p(e-1.42t/t_p)$

GRAPH 1

GRAPH 2

WATER LEVEL (ft)

STORAGE (1000 ft³)

WATER LEVEL (ft)

DISCHARGE (cfs)

# HYDROGRAPH



Q (cfs)

40
30
20
10
0

TIME (MIN)

0   10   20   30   40   50

STORAGE

INFLOW (FROM INFLOW HYDROGRAPH TABLE)
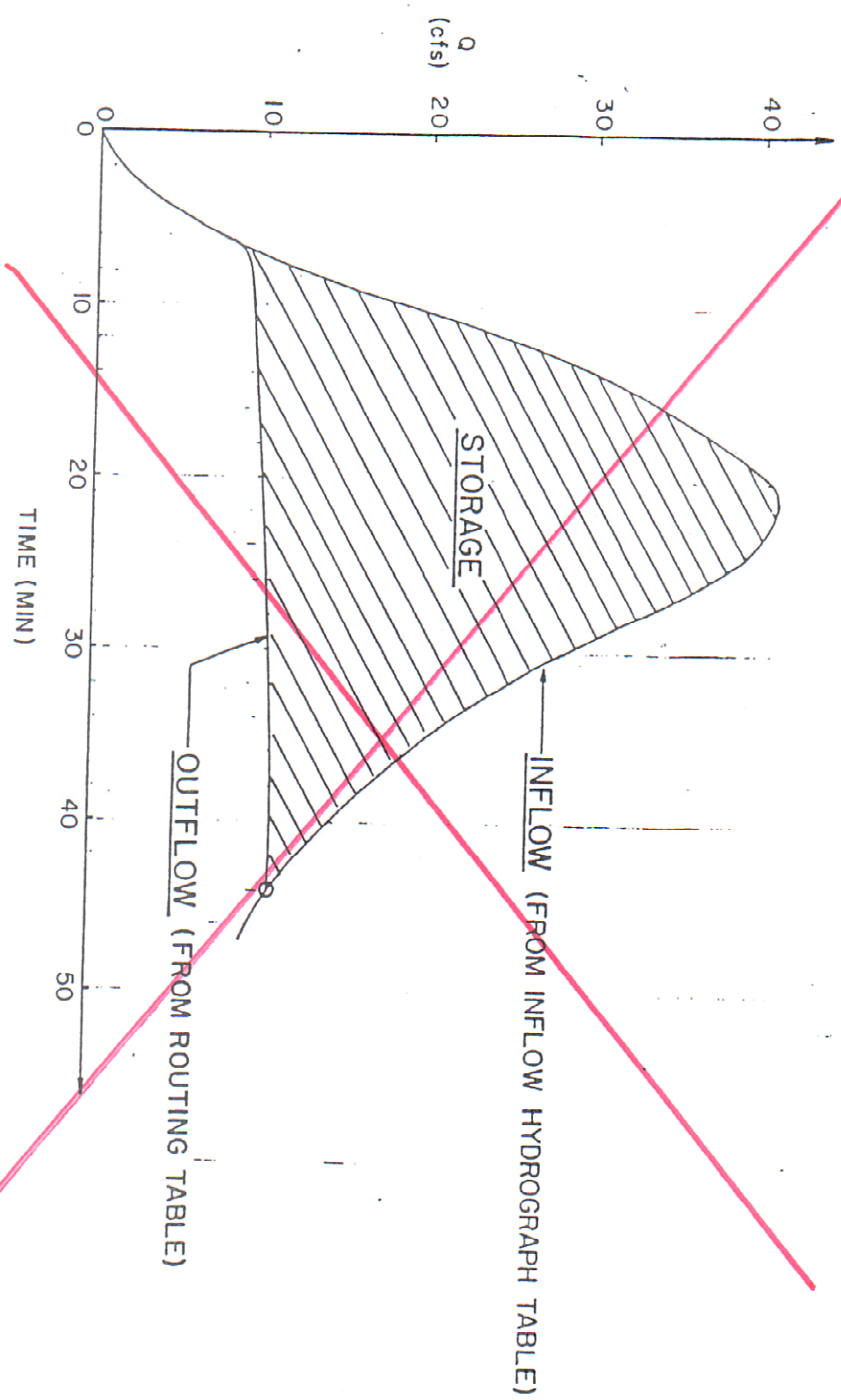
OUTFLOW (FROM ROUTING TABLE)

Set $\Delta t = t_p/10 = 2.1$ min, ound down to 2 min)

Then: $\Delta S_{ij} = (I_i - O_i)(2\text{min})(60 \text{ sec/min}) = \Delta s$ in ft$^3$

## ROUTING TABLE

| i/j | TIME (min) | INFLOW (cfs) | STORAGE (cu ft) x 1000 | OUTFLOW (cfs) |
|---|---|---|---|---|
| 1 | 0 | 0.0 | 0.0 / ΔS=0.0 | 0.0 |
| 2 | 2 | 0.9 | 0.0 / 0.11 | 0.0 |
| 3 | 4 | 3.8 | 0.11 / 0.46 | 0.0 |
| 4 | 6 | 7.7 | 0.57 / 0.57 | 3.0 |
| 5 | 8 | 12.0 | 1.14 / 0.31 | 9.4 |
| 6 | 10 | 18.5 | 1.45 / 1.09 | 9.4 |
| 7 | 12 | 25.0 | 2.54 / 1.86 | 9.5 |
| 8 | 14 | 30.5 | 4.40 / 2.51 | 9.6 |
| 9 | 16 | 34.7 | 6.91 / 3.00 | 9.7 |
| 10 | 18 | 38.5 | 9.91 / 3.44 | 9.8 |
| 11 | 20 | 40.5 | 13.35 / 3.67 | 9.9 |
| 12 | 22 | 40.8 | 17.02 / 3.68 | 10.1 |

| i/j | TIME (min) | INFLOW (cfs) | STORAGE (cu ft) x 1000 | OUTFLOW (cfs) |
|---|---|---|---|---|
| 13 | 24 | 39.4 | 20.70 / 3.49 | 10.3 |
| 14 | 26 | 36.8 | 24.19 / 3.17 | 10.4 |
| 15 | 28 | 32.3 | 27.36 / 2.62 | 10.5 |
| 16 | 30 | 28.5 | 29.98 / 2.15 | 10.6 |
| 17 | 32 | 24.6 | 32.13 / 1.67 | 10.7 |
| 18 | 34 | 21.2 | 33.80 / 1.25 | 10.8 |
| 19 | 36 | 18.8 | 35.05 / 0.96 | 10.8 |
| 20 | 38 | 16.5 | 36.01 / 0.67 | 10.9 |
| 21 | 40 | 14.7 | 36.68 / 0.46 | 10.9 |
| 22 | 42 | 12.7 | 37.14 / 0.22 | 10.9 |
| 23 | 44 | 10.8 | 37.36 / -0.012 | 37.36—PEAK—10.9 |
| 24 | 46 | 9.6 | 37.35 | 10.9 |

## ROUTING RESULTS

| ITEM | | AS ROUTED | PRELIMINARY DESIGN |
|------|------|-----------|--------------------|
| 1. | Outflow Peak (cfs) | 10.9 | 11.0 |
| 2. | Storage Volume (ft3) | 37,360.0 | 38,125.0 |
| 3. | Water Level (ft) | 12.0 | 12.0 |

## CONCLUSION

The facility is slightly overdesigned but is so close to the target design that there will be no need to rework the problem.

Once the design impoundment facility has reached it's capacity, a secondary device or "Emergency Spillway" will discharge the excess runoff in such a way that no danger to loss of life or facility is created.

1. Allow for any additional runoff to flow through a weir in the curb behind the grated inlet.

2. Design the weir for the peak 100-year storm as in the Sediment Basin design example contained in this manual in section 20.

# DETENTION BASIN PROCEDURES

EXAMPLE No. 2

## GIVEN DATA:

A 20 acre parking lot drains to one side, where there is a potential pond site of 175 ft. x 300 ft. in size adjacent to a small stream. The parking lot is almost square.

## DESIGN REQUIREMENT:

Design a holding pond to control the peak outflow from the 10-year storm to no more than the peak flow before development.

## MAXIMUM RELEASE RATE:

The maximum permissible release rate equals the peak 10-year discharge for the site prior to development, C = 0.30 (Chart SD-3), A = 20 AC. Using topo map of unimproved site, locate the point of design and the most remote point from the design site.

$$\text{Length of travel} = 950'$$
$$\text{Height of remote point} = 6.5'$$

$Tc = (10.5) \times 2 = 21$ minutes (Chart SD-2) for overland flow, multiply Tc by 2. Assume Tc = Duration $\therefore$ i = 4.9 in/hr (Chart SD-1)

$$Q = CiA = (0.30)(4.9)(20) = 29.4 \text{ cfs}$$

Maximum permissible release rate = 30 cfs

## PEAK RUNOFF: (DEVELOPED)

Calculate the peak runoff rate for a 10-year storm assuming the site is developed. C(developed) = 0.95 (Chart SD-3). Using the site plan showing proposed conditions, locate the point of design and the most remote point on the site.

$$\text{Length of travel} = 950'$$
$$\text{Height of remote point} = 5'$$

## INFLOW HYDROGRAPH:

$T_c = (11.6) \times 0.4 = 4.6$ minutes (Chart SD-2), for overland flow,
concrete or asphalt surfaces, multiply $T_c$ by 0.4.
Assume $T_c$ = Duration ... $i$ = 7.5 in/hr (Chart SD-1)

$$Q = CiA = (0.95)(7.5)(20) = 142.5 \text{ cfs}$$
Peak inflow (developed) = 142 cfs

A. Peak Flow: $Q_p$ (developed conditions) = $CiA$ = 142 cfs

B. Runoff:  $S = 1,000/CN - 10 = 1.11$ inches (Rf: SCS TR-55)

C. Precipitation (Rf: U. S. Weather Bureau TP - 40)
   $P = 10$ year - 6-hr. rain = 4.40 inches (Chart SWD-03)

$$\text{Runoff} = \frac{(P-0.2S)^2}{P+0.8S} = 3.30 \text{ inches (Rf: SCS TR-55)}$$

D. Time to Peak: Use the pattern hydrograph (Rf: SCS, National Engineering
   Handbook) to set $T_p$ such that the hydrograph peaks at 142 cfs and
   contains 3.3 inches of runoff. Set the volume under the hydrograph at
   the 10-year 6-hr. runoff.

$$T_p = \frac{Vol}{1.37 \ Q_p} = \frac{(3.30 \text{ in})(20 \text{ AC})(1 \text{ ft})(1 \text{ min})}{(1.37)(142 \text{ cfs})(12 \text{ in})(60 \cdot \text{sec})} \quad (43,560 \text{ ft}^2/\text{acre})$$

$$T_p = 20.5 \text{ SAY } 21 \text{ min.}$$

Let the hydrograph peak at the 10-year rational flow with $C = 0.95$.
Set the volume under the hydrograph at the 10-year, 6-hr. runoff.
Use CN = 90 (Rf: SCS TR-55)

```
┌─────────────────────┐
│  INFLOW HYDROGRAPH   │
│    Qp  =  142 cfs    │
│    Tp  =   21 min    │
└─────────────────────┘
```

Estimate storage by the Triangular Hydrograph Approximation

$S_r = (Q_p - Q_o)T_p$   Note:  $Q_o$ is Max. Permissible Outflow

$S_r = (142 \text{ cfs} - 30 \text{ cfs})(21 \text{ min})(60 \text{ sec/min}) = 141,120 \text{ ft}^3$

$S_r = 141,120 \text{ ft}^3$   Estimated Storage Required

Provide some excess, say 10%

Therefore storage = $(1.10)(141,120) = 155,232$ SAY 155,000 ft$^3$

Let the pond depth be 5 ft.

Then,

Area required = $\dfrac{155,000}{5} = 31,000 \text{ ft}^2$

Try a rectangle 130' x 240'

## OUTLET DEVICE:

Knowing the maximum release rate (30 cfs), choose a pipe(s) which will cause the water to rise to a depth of 5' when the pipe is operating at 30 cfs.  Use the orifice equation or Chart SD-e to select the appropriate number and size of the pipe(s).

$Q = C_D A \sqrt{2gh}$  ...  Orifice Equation

where:

| | | |
|---|---|---|
| Q | = | 30 cfs (Peak Outflow) |
| $C_D$ | = | 0.52 (mitered to conform to slope)(Chart SD-e) |
| g | = | 32.2 ft/sec |
| h | = | head from the centerline of the pipe (ft) |
| A | = | cross-sectional area of pipe (ft) |

Choose: C.M. pipe(s) with Q = 30 cfs

| No. Pipes | Dia. | HW |
|---|---|---|
| 3 | 15 | 4.4 |
| 2 | 18 | 4.9 |
| 1 | 24 | 6.2 |

→use (2x18") C.M. pipe with
h = 4.1' and HW = 4.9'

PLOT STAGE DISCHARGE ON GRAPH-2

## ROUTING FOR CONFIRMATION:

STAGE STORAGE RELATION

| Width x Length (ft) | Water Level (ft) | Area (ft2) | Incremental Volume (ft3) | Accumulated Volume (ft3) |
|---|---|---|---|---|
| 130x240 | 0 | 31,200 | | 0 |
| 136x246 | 1 | 33,456 | 32,328 | 32,328 |
| 142x252 | 2 | 35,500 | 34,478 | 66,806 |
| 148x258 | 3 | 38,184 | 36,842 | 103,648 |
| 154x264 | 4 | 40,656 | 39,420 | 143,068 |
| 160x270 | 5 | 43,200 | 41,928 | 184,996 |
| 166x276 | 6 | 45,816 | 44,508 | 229,504 |
| 172x282 | 7 | 48,504 | 47,160 | 276,664 |

└— Plot on Graph 1 ——┘

GRAPH. 1

GRAPH 2

WATER LEVEL (ft)

STORAGE (1000 ft³)

WATER LEVEL (ft)

DISCHARGE (cfs)

REVISIONS

NO. DATE | DESCRIPTION

APPROVED: DATE  May 8, 1980

STD. NO. | REV.
6027
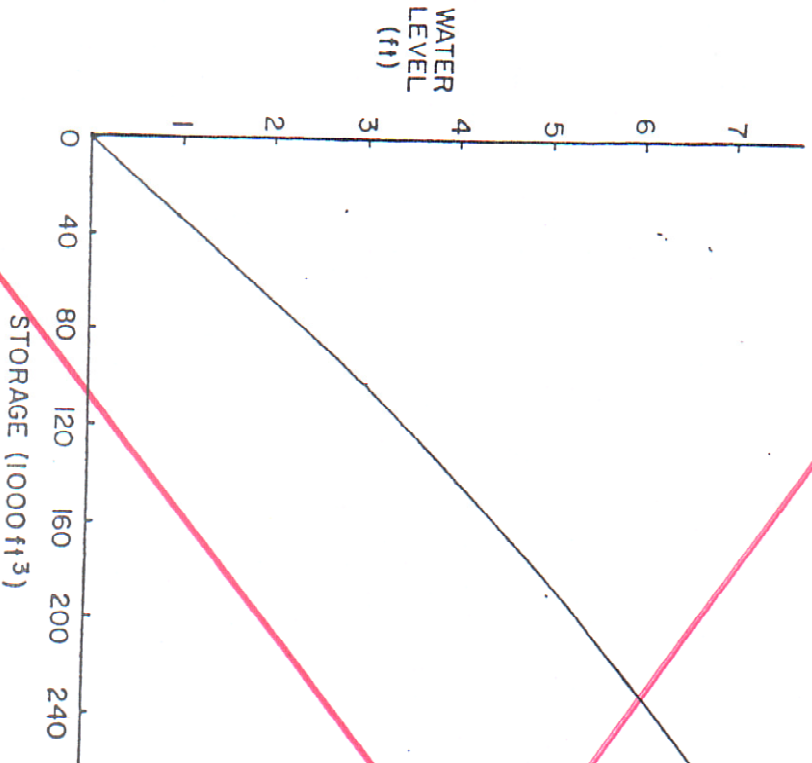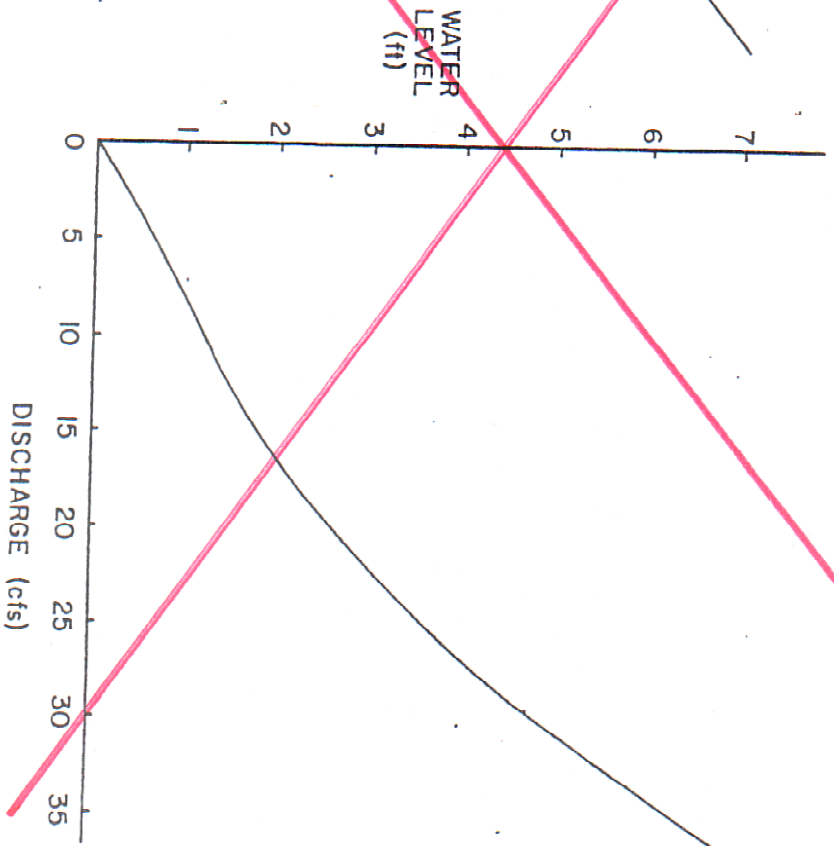
# INFLOW HYDROGRAPH:

$Q_p = 142$ cfs
$T_p = 21$ min } Previously computed

Dimensionless Hydrograph Coordinates
(To be used for the 6-hour approximation)          (Chart SWD-02(2))

| $t/t_p$ | $Q/Q_p$ (Step Function) | $t$ ($t/t_p \times T_p$) | $Q$ ($Q/Q_p \times Q_p$) |
|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 |
| 0.1 | 0.024 | 2.1 | 3.41 |
| 0.2 | 0.095 | 4.2 | 13.49 |
| 0.3 | 0.21 | 6.3 | 29.82 |
| 0.4 | 0.35 | 8.4 | 49.70 |
| 0.5 | 0.50 | 10.5 | 71.00 |
| 0.6 | 0.65 | 12.6 | 92.30 |
| 0.7 | 0.79 | 14.7 | 112.18 |
| 0.8 | 0.90 | 16.8 | 127.80 |
| 0.9 | 0.98 | 18.9 | 139.16 |
| 1.0 | 1.00 | 21.0 | 142.00 |
| 1.1 | 0.98 | 23.1 | 139.16 |
| 1.2 | 0.90 | 25.2 | 127.80 |
| 1.3 | 0.85 | 27.3 | 120.70 |
| 1.4 | 0.74 | 29.4 | 105.08 |
| 1.5 | 0.64 | 31.5 | 90.88 |
| 1.6 | 0.55 | 33.6 | 78.10 |
| 1.7 | 0.48 | 35.7 | 68.16 |
| 1.8 | 0.42 | 37.8 | 59.64 |
| 1.9 | 0.36 | 39.9 | 51.12 |
| 2.0 | 0.31 | 42.0 | 44.02 |
| 2.1 | 0.27 | 44.1 | 38.34 |
| 2.2 | 0.24 | 46.2 | 34.08 |
| 2.3 | 0.20 | 48.3 | 28.40 |
| 2.4 | 0.18 | 50.4 | 25.56 |
| 2.5 | 0.15 | 52.5 | 21.30 |
| 2.6 | 0.13 | 54.6 | 18.46 |

Set $\Delta t = t_p/10 = 2.1$ min, (Round to 2 min)

Then: $\Delta S_{ij} = (I_i - O_i)(2\ \text{min})(60\ \text{sec/min})\quad \Delta s$ in ft³

## ROUTING TABLE

| TIME (min) | INFLOW (cfs) | STORAGE (1000 ft³) | OUTFLOW (cfs) | TIME (min) | INFLOW (cfs) | STORAGE (1000 ft³) | OUTFLOW (cfs) |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.0 / S=0.0 | 0 | 26 | 123 | 111.48 / 12.00 | 23 |
| 2 | 3 | 0.0 / 0.36 | 0 | 28 | 115 | 123.48 / 10.80 | 25 |
| 4 | 12 | 0.36 / 1.44 | 0 | 30 | 100 | 134.28 / 8.88 | 26 |
| 6 | 27 | 1.80 / 3.24 | 0 | 32 | 88 | 143.16 / 7.32 | 27 |
| 8 | 45 | 5.04 / 5.40 | 1 | 34 | 77 | 150.48 / 6.00 | 27 |
| 10 | 66 | 10.44 / 7.68 | 2 | 36 | 67 | 156.48 / 4.68 | 28 |
| 12 | 87 | 18.12 / 10.08 | 3 | 38 | 58 | 161.16 / 2.76 | 28 |
| 14 | 107 | 28.20 / 12.12 | 6 | 40 | 51 | 163.92 / 2.64 | 28 |
| 16 | 123 | 40.32 / 13.56 | 10 | 42 | 45 | 166.56 / 1.92 | 29 |
| 18 | 135 | 53.88 / 14.52 | 14 | 44 | 39 | 168.48 / 1.20 | 29 |
| 20 | 141 | 68.40 / 14.88 | 17 | 46 | 34 | 169.68 / 0.60 | 29 |
| 22 | 141 | 83.28 / 14.64 | 19 | 48 | 30 | 170.28 / 0.12 | 29 |
| 24 | 135 | 97.92 / 13.56 | 22 | 50 | 26 | 170.40 | 29 |

HYDROGRAPH

Q
(cfs)

160
140
120
100
80
60
40
20
0

0   10   20   30   40   50

TIME (MIN)

STORAGE

INFLOW (FROM INFLOW HYDROGRAPH)

OUTFLOW (FROM ROUTING TABLE)

| ITEM | A. ROUTED | PRELIMINARY DESIGN |
|------|-----------|--------------------|
| 1. Outflow Peak (cfs) | 29.0 | 30.0 |
| 2. Storage Volume (ft)³ | 170,400.0 | 155,000.0 |
| 3. Water Level (ft) | 4.7 | 5.0 |

## CONCLUSION:

The basin is slightly overcontrolled for this storm. If more accuracy is desired, try a slightly larger pipe, a weir, or a little less storage (at a greater depth).

## FURTHER DESIGN WORK NECESSARY:

Once the facility has reached its capacity, a secondary device or "Emergency Spillway" will discharge the excess runoff in such a way that no danger to loss of life or facility is created.

Design the weir for the peak 100-year storm. Allow for any additional runoff to flow through a weir in the curb adjacent to the stream.

Size the weir to carry the 100-year storm ($Q100$).
Set the height of the Emergency Spillway at the 25-year storm.

Height of Emergency Spillway = 5.6'

(Spillway height determined by routing the 25-year storm).

For: Tc = 4.6 (previously calculated)
i = 10 in/hr (Chart SD-1) for 100-year storm
Q100 = CiA = (0.95)(10)(20) = 190 cfs

Use maximum velocity of 5 ft/sec over emergency spillway:

$$Q = C_w \times L \times H^{3/2}$$

$$V = \frac{Q}{A} = \frac{C_w \times L \times H^{3/2}}{(2/3) \times (H) \times (L)}$$

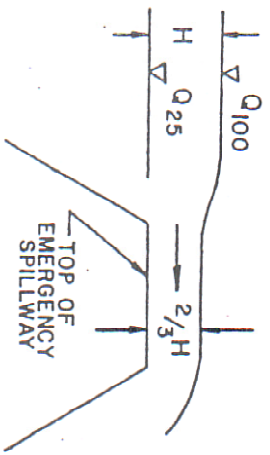$$(C_w = 3.0 \text{ for broad crested weir})$$

$$V = 4.5 \times H$$

$$H_{allow} = (V/4.5)^2, \quad (\text{use } V = 5 \text{ ft/sec})$$

$$H_{allow} = 1.23 \text{ ft}$$

$$L = \frac{Q_{100}}{(C_w) \times (H_{allow})^{3/2}}, \quad (\text{for } V = 5 \text{ ft/sec})$$

$$L = \frac{190}{3 \times 1.15} = 55.07 \text{ SAY } 55 \text{ ft. for length of weir}$$
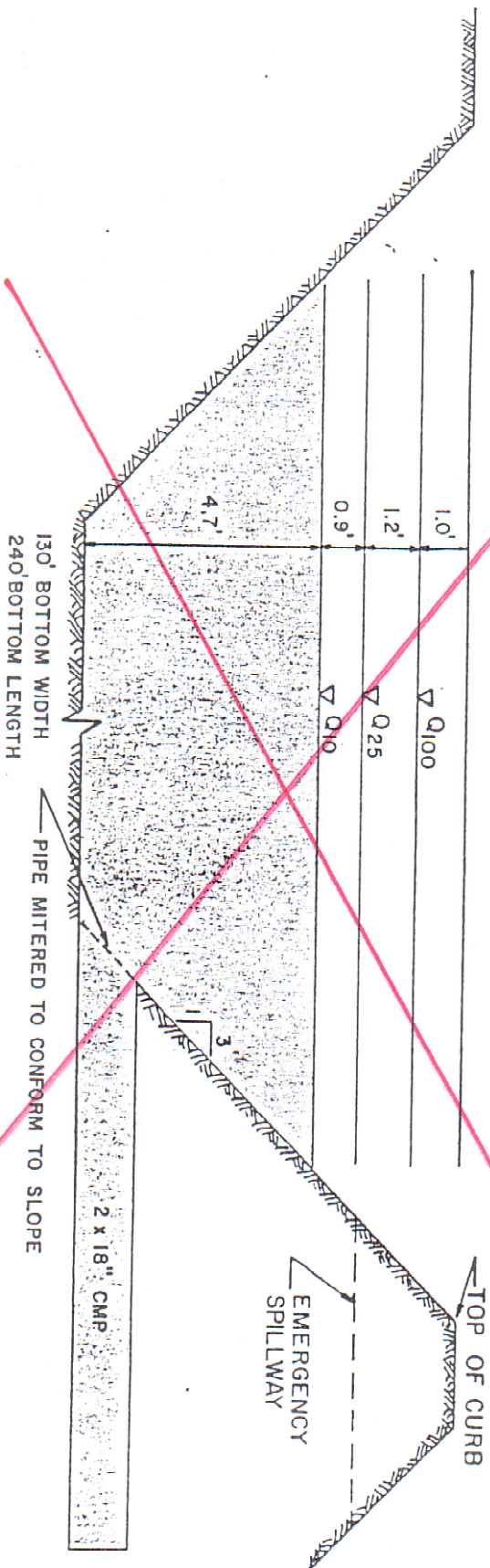


Q100  
Q25  
H  
2/3 H  
TOP OF EMERGENCY SPILLWAY

## SUMMARY SKETCH:

1.0'

1.2' ▽ Q100

0.9' ▽ Q25

▽ Q10

4.7'

3

130' BOTTOM WIDTH
240' BOTTOM LENGTH

PIPE MITERED TO CONFORM TO SLOPE

2 x 18" CMP

TOP OF CURB

EMERGENCY SPILLWAY